Government of **Western Australia**
Department of **Water**

Methods used to estimate total surface water use and agricultural demand in the Whicher area

Looking after all our water needs

Department of Water
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Department of Water
168 St Georges Terrace
Perth Western Australia 6000
Telephone +61 8 6364 7600
Facsimile +61 8 6364 7601
www.water.wa.gov.au

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The authors appreciate edits by Natasha Pauli.

For more information about this report, contact:

Katherine Bennett
Phone: 08 6364 6567
Email: Katherine.Bennett@water.wa.gov.au.

Recommended reference

Bennett, K & Donohue, R 2009, *Methods used to estimate total surface water use and agricultural demand in the Whicher area*, Department of Water, Government of Western Australia, Perth.

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Summary

The Department of Water have estimated total surface water use in each of the 52 subareas of the Whicher Area in the south west of Western Australia. We used the estimates to support decision making as part of development of the *Whicher area surface water allocation plan* (DoW 2009b), to set allocation limits and to determine the amount of water available for new licences.

Estimates of agricultural surface water use and demand were identified as a priority given that agriculture in the Whicher area accounts for a significant proportion of total water use in south west Western Australia, and that prior to proclamation in September 2007, was largely unlicensed.

This report describes and records the methods we used to estimate total surface water use and agricultural demand in the Whicher area.

Method

The two approaches we used to define agricultural water use in the Whicher area were:

- *total dam water storage volume* (capture of surface water flows); using farm dam mapping at 1:25 000 to calculate surface area and volume in 43 of the 52 Whicher subareas
- *total agricultural water demand* (taken from surface water or groundwater); using land-use mapping and water demand for agriculture in 52 of the Whicher subareas.

The Whicher area is characterised by on-stream farm dams that capture surface water, mostly for agricultural use. The storage volume of farm dams is therefore considered a good indicator of total agricultural surface water use in the area.

At the time of the of the investigation farm dam mapping for the area was incomplete. The farm dam mapping was therefore supplemented with estimates of total agricultural demand using land use mapping and crop demand to develop a complete estimate of water use in the Whicher area.

The two methods, used in conjunction with information on surface water and groundwater entitlements, and anecdotal information on water use practices in the area, also allowed estimates of agricultural water use to be divided into groundwater and surface water use.

We then combined the estimate of agricultural surface water use with estimates for other consumptive uses in the area (e.g. public water supply) to calculate total surface water use in the Whicher area.

Results

Using the total agricultural water demand method, we estimated total water demand for agriculture in the Whicher area to be 49.6 GL/year.

Irrigated pasture and crops had the highest water demand of all land uses, using an estimated 15.7 GL/year, which is about 30 per cent of total water use in the Whicher area.

Irrigation for perennial horticulture and tree fruits had the second-highest water demand, using an estimated 13.4 GL/year. Grapevines were the third-highest user of irrigation water, using 8.5 GL/year. Stock drinking water (as defined by the area of non-irrigated grazing pasture) was estimated as having a relatively small annual water demand of 1.5 GL/year.

Using a combination of the total agricultural demand method, farm dam storage estimates, licensed groundwater entitlements and anecdotal information, we estimated agricultural surface water use in the Whicher area to be 31.5 GL/year. Combining this with other consumptive surface water uses such as public water supply, total surface water use in the Whicher area was estimated at 33.5 GL/year, with the highest use in the Capel River North (4.7 GL/year) and Wilyabrup (3.1 GL/year) subareas.

Discussion

Although the total agricultural demand and dam storage methods produced different results, the combination of both has strengthened the final estimates of agricultural and total surface water use.

The combination of the two methods allowed us to supplement farm dam storage estimates where dam mapping was absent, but also enabled the incorporation of water use abstracted via direct pumping in some sub areas, and the partitioning of water use according to ground and surface water use.

Licensing is underway in the proclaimed areas of the Whicher Area and will be useful in determining the accuracy of the methods discussed in this report. In the event that the methods in this report are applied to other areas, or the unproclaimed Whicher areas continue to rely on these methods, it is recommended that:

- ground-truthing for land-use mapping and dam mapping takes place
- water-use estimates are updated as more accurate crop-demand and land-use mapping becomes available
- the equation used to calculate storage is updated to suit different regions as better information becomes available.

This is the first time the department has undertaken this comprehensive study and employed these methods to estimate unknown surface water use for allocation planning. This work represents a step forward in consistently estimating water use over large areas of land.

1 Water resource planning in the Whicher area

1.1 The study area

The Whicher area is located in south west Western Australia. It covers an area of 6584 km^2, bounded to the north by Bunbury, to the east by the Whicher scarp, to the south by the Donnelly River catchment, and to the west by the Indian Ocean. The Whicher area includes the Capel, Margaret and lower Blackwood rivers and their tributaries, as well as a number of smaller, westward-flowing streams that discharge into the Indian Ocean (Figure 1). The Whicher area is split into 52 subareas largely based on surface water catchments.

Agriculture uses up to 70 per cent of all water used in the Whicher area. Water use in this sector is largely characterised by self-supply from small- to medium-sized farm dams (Figure 2). Farm dams in the region are mostly gully-wall dams constructed on-stream to intercept and store rainfall runoff for the irrigation season. Gully-wall dams also supply water for stock and domestic purposes.

Most of the Whicher surface water area was not proclaimed under the *Rights in Water Irrigation Act 1914* (WA) until September 2007. As a result, the area was largely unlicensed and the volume of surface water used was not recorded.

Figure 1 Whicher surface water management area showing subareas and proclaimed surface water areas

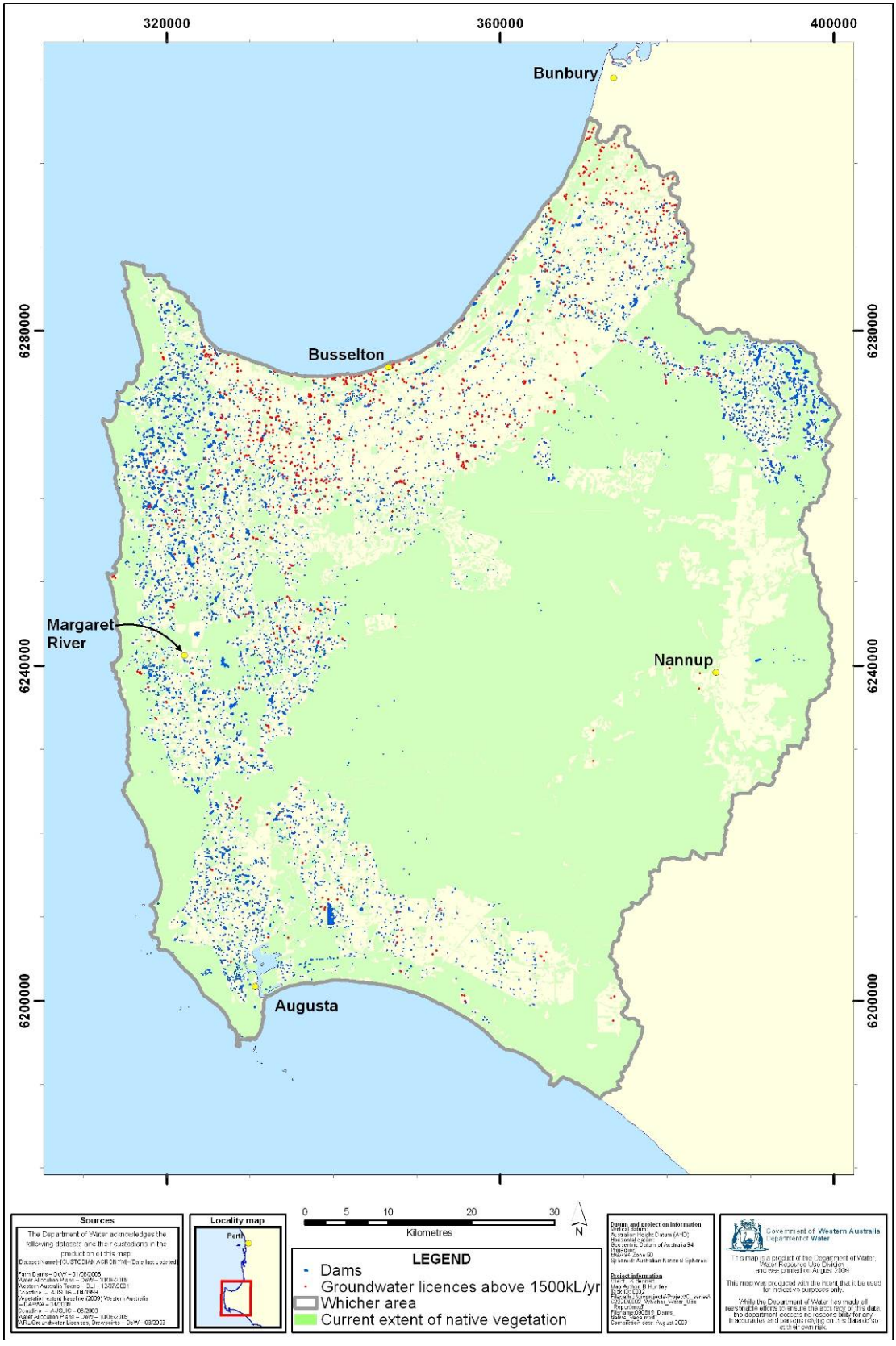

Figure 2 Remnant vegetation, groundwater licences and farm dams. Regions where farm dams and cleared areas intercept indicate self-supply from surface water

1.2 Purpose of this report

This report documents the methods used to estimate total surface water use in the Whicher area and forms part of the supporting information used for allocation planning, setting of allocation limits and water-use licensing.

For more information about allocation planning in the Whicher area, refer to DoW 2009a and 2009b. Definitions of terms specific to this report are provided in Table 1.

As discussed earlier, when planning began in 2007, limited quantitative data on water demand were available to support the allocation strategy. While some licensed surface water entitlements were in place for mining and public water supply, agricultural water use was largely unquantified. The department employed two methods to estimate agricultural use:

- total agricultural demand, calculated based on the varying water requirements of different agricultural land-use type, and the areas occupied by each land use
- total storage volume of self-supply dams, calculated based on the surface area and density of dams.

These methods were used in combination with licensed-use information, water-use reports and expert opinion to inform the water allocation plan.

This report presents the dam storage and agricultural water-demand estimate methods, and how these were used to estimate total surface water use. This is the first time the department has undertaken such a comprehensive study and employed these methods to estimate unknown water use for allocation planning. This work represents a step forward in estimating unknown water use in a consistent way over large areas of land.

Table 1 Definition of terms specific to this report

Term	Definition
Total agricultural demand	Refers to the sum of the water used for agricultural activities, such as the irrigation of commercial crops or drinking water for livestock, regardless of the method of capture (pumping or interception) or source of supply (surface water or groundwater). For the purpose of this report, total agricultural demand also includes water used for irrigating recreational areas such as ovals and public gardens.
Surface water agricultural demand	The proportion of total agricultural demand that is sourced from surface water.
Total surface water use	The total amount of consumptive surface water used. This includes surface water used for irrigation and agriculture, mining and industry, recreation, and domestic purposes.
Total dam storage	Refers to the maximum amount of water a dam is physically able to store at any given time.

The following three sections of this report outline the methods used to derive estimates of each component of water demand. A brief overview of the results is presented, followed by a discussion of the accuracy and applicability of the results. The final section of the report outlines recommendations to improve the accuracy of estimates for water demand.

2 Total agricultural demand

This section describes the methods used to estimate the total agricultural demand in the Whicher area. For the purpose of this report, total agricultural demand refers to the sum of the water used to irrigate agricultural and recreational areas, and provide drinking water for stock (see Table 1). As discussed, total agricultural demand does not distinguish whether the water source is surface water, groundwater, or a combination of both.

A range of irrigated crops is grown commercially in the Whicher area, including pastures, vegetables, perennial fruits and grapes. The annual volume of water needed to irrigate these crops depends on the crop type, irrigation method, length of the irrigation season, position in the landscape, soil type, volume and seasonality of rainfall, temperature and evaporation.

It should be noted that although most stock water use is exempt from licensing, it was included in the overall water use for agriculture. This was to improve the quality of the information available for setting of allocation limits. Further, although irrigated recreational areas are not part of the agricultural sector, estimates of their water use have also been included within total agricultural demand, because this use was not accounted for elsewhere, and makes a substantial contribution to consumptive water use.

2.1 Methods

In the 52 Whicher subareas the total volume of water needed to irrigate commercial crops and recreational areas, as well as provide drinking water for stock, was estimated by multiplying the area (in hectares) occupied by each land-use type, and the water demand of that land-use type per hectare per year. The methods for calculating area and land-use demand are outlined below.

2.1.1 Estimating the area for each land-use type

The area of each land-use type was estimated from land-use mapping undertaken by the Department of Water in conjunction with the Department of Agriculture and Food (DAFWA). Land-use maps were based on aerial photography supplied by Landgate. Figure 3 illustrates the dates that aerial photos were captured across the Whicher region. It should be noted that the land-use mapping represents land use on the date the aerial imagery was captured. The dates of image capture vary across the Whicher area from November 2004 to March 2007.

All land uses were mapped and classified according to Australian Land Use Management (ALUM) criteria (see Appendix A for further detail on ALUM categories). Land-use boundaries were visually identified, and digitised and classified using the GeoMedia Professional geographic information system. Figure 4 shows an example of the land-use mapping. The total area for each ALUM land-use class was calculated for each subarea.

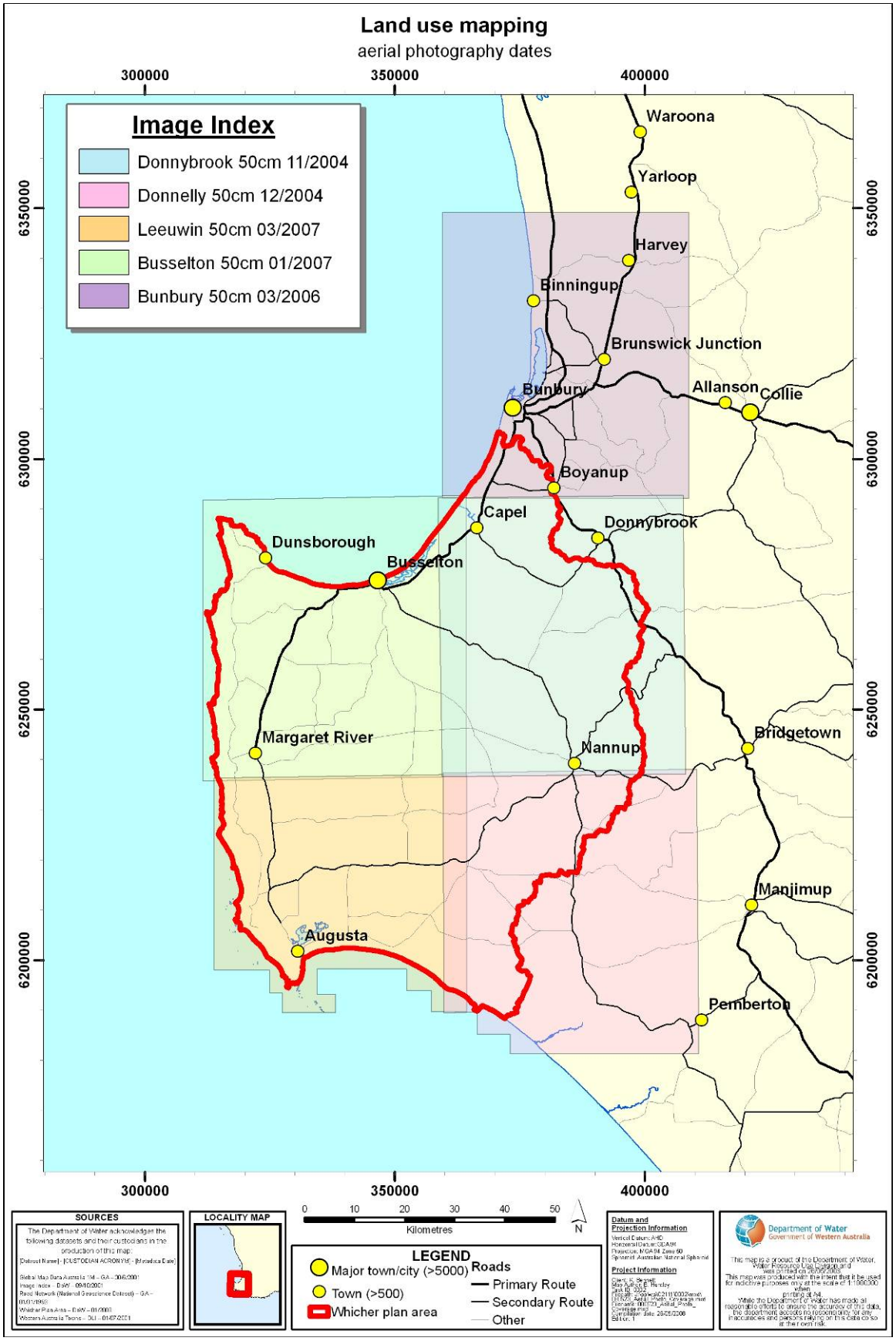

Figure 3 The date and extent of the aerial photography used in the land-use mapping

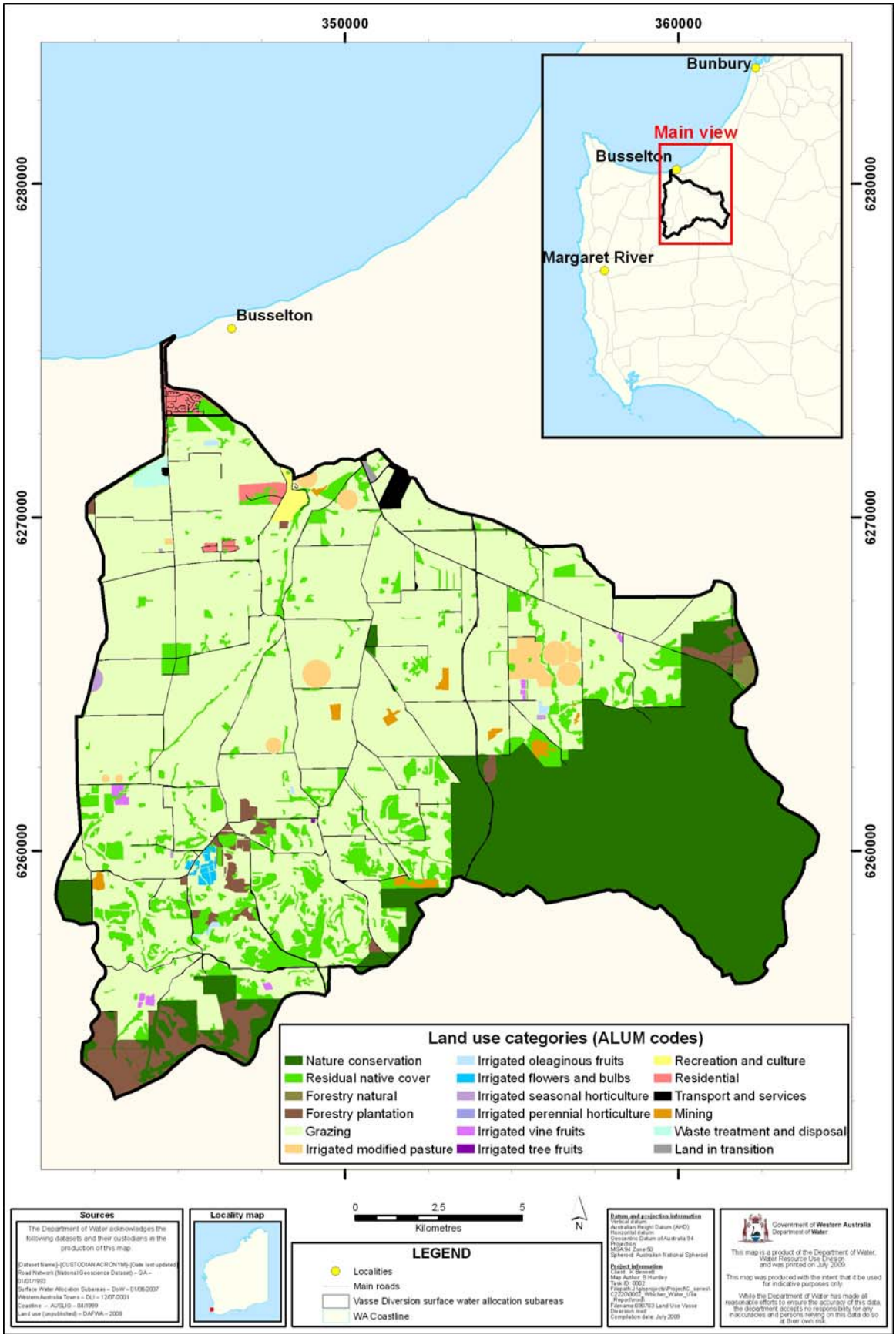

Figure 4 Land-use mapping and ALUM classifications for the Vasse Diversion surface water subarea

2.1.2 Estimating water demand for land uses

For this study, crop and recreational demand per hectare was estimated using the DAFWA Irrigation Calculator v4.0 (DAFWA 2004; Lantzke et al. 2004). The calculator is based on a set of user-defined parameters covering crop type, soil type, geographical location, irrigation season and irrigation method.

For this study, some of the calculator's options (crop type, soil type and rainfall zone) did not match exactly the parameters found in the subareas. In subareas where it was impossible to distinguish between two applicable options, the option resulting in the highest water demand was selected so that total crop demand at the subarea scale was not underestimated. Appendix B provides detail on the options chosen in the calculator for each of the ALUM land-use types.

Water demand for livestock was determined using estimates of stock carrying capacity (number of animals/ha) and stock drinking rates (kL/animal/yr). Stock water demand was based on data collected in water-use surveys conducted in the Wilyabrup subarea in 2006 (DoW 2006, unpublished). Stock drinking rates were taken from the department's internal *General water application rates*. As the ALUM coding system does not allow for differences among grazing animals (e.g. dairy cattle, sheep and beef cattle), it was assumed all mapped grazing land was stocked by beef cattle. Water-use rates for beef cattle were chosen because this is the most common grazing type in the region.

2.2 Results

2.2.1 Area occupied by irrigated agriculture, grazing land and recreational areas

Approximately 10 820 ha are irrigated each year in the Whicher area; key crops include grapes, fruit orchards, perennial horticulture and seasonal horticulture. An additional 176 318 ha are occupied by grazing pastures that are not irrigated. Estimates of stock drinking water requirements on grazing pastures were included in the results outlined here. Detailed information on the area occupied by each type of land-use category is provided in Table 2.

For ease of reference, in the tables that accompany the results section below, ALUM classifications of crop types that had similar water demand were combined. For example, 'irrigated modified pasture', 'irrigated legume/pasture mixture' and 'irrigated cropping' were all combined in the broad category 'irrigated pasture and crops'.

Table 2 Area of land in hectares occupied by each crop type (ALUM classification) in each of the Whicher subareas

Crop type	Grazing pasture	Irrigated pasture and crops	Perennial hort and tree fruits	Olives	Tree nuts	Grapes	Shrub fruits	Flowers	Vegetables	Seasonal fruits	Intensive horticulture	Recreation and culture	Total area (ha)
ALUM code	**2.1.0 + 3.2.1**	**4.2.0 + 4.2.3+4.3.0**	**4.4.0 + 4.4.1**	**4.4.2**	**4.4.3**	**4.4.4**	**4.4.5**	**4.4.6**	**4.5.0 + 4.5.4**	**4.5.1**	**5.1.0**	**5.5.3**	
Subarea													
10 Mile Brook	7												7
Adelaide													
Ballan													
Beenup	873	148											1021
Biljedup	214					26							240
Boodijidup	2140					479						1	2619
Bramley	2177		27			38							2242
Buayanyup	12713		155	45		463		17	338			9	13740
Calgardup	1143					53							1196
Capel River (central)	1196	1	124			25			10				1356
Capel River (north)	3552	2	399		6	27	2		18		1		4006
Capel River (south)	5563	122	114	9		4			37				5848
Capel River (west)	4910	116	34			44			44				5148
Carbunup	9423		17	3		448		47	40				9977
Carlotta	3733		35		7							9	3784
Chapman	2835		2			358							3195
Chapman (upper)	3657	12		10		539			1				4218
Cowaramup	1189		3	41	6	7							1247
Dunsborough coast	9210		47	60		682		31	40		6		10074
Ellen	1388		7			90							1485
Ellis													
Five Mile Brook	4159	71	12			39						52	4333
Glenarty	1853					189							2043
Gunyulgup	2643		7	8		325		11					2994
Gynudup Br/Tren Creek	12242	138	17			38			32	13		4	12485
Lwr Blackwd	6368	51	2	3		33			6				6461

Crop type	Grazing pasture	Irrigated pasture and crops	Perennial hort and tree fruits	Olives	Tree nuts	Grapes	Shrub fruits	Flowers	Vegetables	Seasonal fruits	Intensive horticulture	Recreation and culture	Total area (ha)
ALUM code	2.1.0 + 3.2.1	4.2.0 + 4.2.3+4.3.0	4.4.0 + 4.4.1	4.4.2	4.4.3	4.4.4	4.4.5	4.4.6	4.5.0 + 4.5.4	4.5.1	5.1.0	5.5.3	
Lwr Blackwd (Hardy)	1841					15							1856
Lwr Blackwd (Hut)	739		3										742
Lwr Blackwd (Nannup)	3905		51			3	21		1			8	3989
Margaret (lower)	905		11	4		119						32	1071
Margaret (middle)	4538		62	43		208			20				4871
Margaret (upper)	732					49							780
Margaret town	480					21							501
McAtee	10												10
McLeod SW	2925		16	6		134							3081
Milyeannup	29											1	30
Naturalist	1361		4	1		36							1402
Poison													
Quininup	48		2	5		202							257
Readia	0												
Red Gully	99		3										102
Rosa													
Rushy	1315		10			149							1474
Scott	14819	839							63				15720
St John	3582		37										3619
Tanjannerup	112												112
Turner SW	2261		26			6							2293
Turnwood	328												328
Vasse Diversion	16542	388	2	28		52		47	7			76	17142
West Bay	1341		2			86						36	1465
Wilyabrup	5333		5	6		962							6306
Wonnerup	19887	220	6			70			58			23	20264
Total area (ha)	176318	2109	1239	272	19	6021	23	152	715	13	7	251	18713

2.2.2 Land-use water demands

Perennial horticulture and tree fruits, which include apples, pears, citrus, stone fruit and avocados, had the highest rate of water use per hectare, ranging between 8095 kL/ha/yr and 12 222 kL/ha/yr depending on subarea location and the dominant soil type within the subarea. Drinking water demand for stock had the lowest rate of water use per hectare, using around 8.5 kL/ha/yr (Table 3).

Table 3 Water demand per hectare (kL/ha) for the land-use categories in each Whicher subarea

Crop type	Grazing pasture (kL/ha)	Irrigated pasture and crops (kL/ha)	Perennial hort and tree fruits (kL/ha)	Olives (kL/ha)	Tree nuts (kL/ha)	Grapes (kL/ha)	Shrub fruits (kL/ha)	Flowers (kL/ha)	Vegetables (kL/ha)	Seasonal fruits (kL/ha)	Intensive horticulture (kL/ha)	Recreation and culture (kL/ha)
ALUM code	**2.1.0 + 3.2.1**	**4.2.0 + 4.2.3 + 4.3.0**	**4.4.0 + 4.4.1**	**4.4.2**	**4.4.3**	**4.4.4**	**4.4.5**	**4.4.6**	**4.5.0 + 4.5.4**	**4.5.1**	**5.1.0**	**5.5.3**
Subarea												
10 Mile Brook	8.5											
Adelaide												
Ballan												
Beenup	8.5	6370										
Biljedup	8.5					1405						
Boodijidup	8.5					1405						7500
Bramley	8.5		8095			1277						
Buayanyup	8.5		12222	5231		1908		10969	8108			7500
Calgardup	8.5					1405						
Capel River (central)	8.5	7824	11111			1734			7298			
Capel River (north)	8.5	7824	11111		3314	1734	9972		7298		8896	
Capel River (south)	8.5	7824	11111	4756		1734			7298			
Capel River (west)	8.5	8606	12222			1908			8108			
Carbunup	8.5		8095	3581		1277		7284	7197			
Carlotta	8.5		11111		3314							7500
Chapman	8.5		8095			1277						
Chapman (upper)	8.5	5791		3581		1277			7197			
Cowaramup	8.5		8905	3940	2814	1405						
Dunsborough coast	8.5		8905	3940		1405		8012	8547		8547	
Ellen	8.5		8905			1405						
Ellis												
Five Mile Brook	8.5	8606	12222			1908						7500
Glenarty	8.5					1405						
Gunyulgup	8.5		8905	3940		1405		8012				
Gynudup Br/Tren Creek	8.5	8606	12222			1908			8108	10969		7500
Lwr Blackwd (estuarine)	8.5	5791	8095	3581		1277			7197			
Lwr Blackwd (Hardy)	8.5					1405						
Lwr Blackwd (Hut)	8.5		11111									

Crop type	Grazing pasture (kL/ha)	Irrigated pasture and crops (kL/ha)	Perennial hort and tree fruits (kL/ha)	Olives (kL/ha)	Tree nuts (kL/ha)	Grapes (kL/ha)	Shrub fruits (kL/ha)	Flowers (kL/ha)	Vegetables (kL/ha)	Seasonal fruits (kL/ha)	Intensive horticulture (kL/ha)	Recreation and culture (kL/ha)
ALUM code	2.1.0 + 3.2.1	4.2.0 + 4.2.3 + 4.3.0	4.4.0 + 4.4.1	4.4.2	4.4.3	4.4.4	4.4.5	4.4.6	4.5.0 + 4.5.4	4.5.1	5.1.0	5.5.3
Lwr Blackwd (Nannup)	8.5		11111			1734	9972		7298			7500
Margaret (lower)	8.5		8905	3940		1405						7500
Margaret (middle)	8.5		8095	3581		1277			7197			
Margaret (upper)	8.5					1277						
Margaret town	8.5		8095			1277						
McAtee	8.5											
McLeod SW	8.5		8905	3940		1405						
Milyeannup	8.5											7500
Naturalist	8.5		8905	3940		1405						
Poison												
Quininup	8.5		8905	3940		1405						
Readia												
Red Gully	8.5		11111									
Rosa												
Rushy	8.5		8095			1277						
Scott	8.5	6370							8547			
St John	8.5		11111									
Tanjannerup	8.5											
Turner SW	8.5		8905			1405						
Turnwood	8.5											
Vasse Diversion	8.5	8606	12222	5231		1908		10969	8108			7500
West Bay	8.5		8905			1405						7500
Wilyabrup	8.5		8095	3581		1277						
Wonnerup	8.5	8606	12222			1908			8108			7500

2.2.3 Total agricultural demand

The total annual demand for irrigated agriculture, stock drinking water and recreational areas in the Whicher area was calculated at 49.6 GL at the time the photographic imagery used for land-use mapping was captured. Total agricultural demand for each surface water subarea and crop type is shown in Table 4.

Irrigated pasture and crops had the highest overall demand of all land uses, consuming approximately 15.7 GL/year, which represents around 30 per cent of total water use in the Whicher area. Irrigation for perennial horticulture and tree fruits had the second-highest overall water demand, using an estimated 13.4 GL/year. Grapevines and vegetables were the third- and fourth-highest overall users of irrigation water, respectively consuming 8.5 GL and 5.7 GL annually. Stock drinking water (as defined by the area of non-irrigated grazing pasture) used a relatively small volume of water – 1.5 GL/year.

Subareas with the highest estimated level of agricultural demand were Buayanyup and Scott with 6120 ML/year and 6010 ML/year respectively. The subareas with the lowest use were Adelaide, Ballan, Ellis, Poison, Redia and Rosa which all recorded no agricultural water use. These catchments are mostly forested.

Table 4 Total demand by agricultural category in the Whicher subareas

Crop type	Grazing pasture (kL)	Irrigated pasture and crops (kL)	Perennial hort and tree fruits (kL)	Olives (kL)	Tree nuts (kL)	Grapes (kL)	Shrub fruits (kL)	Flowers (kL)	Vegetables (kL)	Seasonal fruits (kL)	Intensive horticulture (kL)	Recreation and culture (kL)	Total agricultural demand (kL)
ALUM code	**2.1.0 + 3.2.1**	**4.2.0 + 4.2.3 + 4.3.0**	**4.4.0 + 4.4.1**	**4.4.2**	**4.4.3**	**4.4.4**	**4.4.5**	**4.4.6**	**4.5.0 + 4.5.4**	**4.5.1**	**5.1.0**	**5.5.3**	
Subarea													
10 Mile Brook	0												
Adelaide													
Ballan													
Beenup	7	945											950
Biljedup	2					36							40
Boodijidup	18					673						5	700
Bramley	19		219			49							290
Buayanyup	108		1895	235		884		185	2741			70	6120
Calgardup	10					74							80
Capel River (central)	10	10	1374			44			75				1510
Capel River (north)	30	15	4430		20	47	18		129		9		4700
Capel River (south)	47	954	1262	41		7			273				2580
Capel River (west)	42	998	412			84			357				1890
Carbunup	80		134	11		572		339	290				1430
Carlotta	32		385		24							69	510
Chapman	24		17			458							500
Chapman (upper)	31	68		36		688			5				830
Cowaramup	10		27	163	16	10							230
Dunsborough coast	78		415	235		958		245	339		48		2320
Ellen	12		61			126							200
Ellis													
Five Mile Brook	35	612	145			75						387	1255
Glenarty	16					266							280
Gunyulgup	22		63	33		457		87					660
Gynudup Br/Tren Creek	104	1192	209			73			262	140		32	2010
Lwr Blackwd (Estuarine)	54	293	13	9		42			42				450
Lwr Blackwd (Hardy)	16					22							340
Lwr Blackwd (Hut)	6		34										40
Lwr Blackwd (Nannup)	33		564			5	213		6			63	880

Crop type	Grazing pasture (kL)	Irrigated pasture and crops (kL)	Perennial hort and tree fruits (kL)	Olives (kL)	Tree nuts (kL)	Grapes (kL)	Shrub fruits (kL)	Flowers (kL)	Vegetables (kL)	Seasonal fruits (kL)	Intensive horticulture (kL)	Recreation and culture (kL)	Total agricultural demand (kL)
ALUM code	**2.1.0 + 3.2.1**	**4.2.0 + 4.2.3 + 4.3.0**	**4.4.0 + 4.4.1**	**4.4.2**	**4.4.3**	**4.4.4**	**4.4.5**	**4.4.6**	**4.5.0 + 4.5.4**	**4.5.1**	**5.1.0**	**5.5.3**	
Margaret (lower)	8		95	16		168						242	530
Margaret (middle)	39		502	154		265			147				1110
Margaret (upper)	6					62							70
Margaret town	4					27							30
McAtee	0												
McLeod SW	25		145	24		188							380
Milyeannup	0											5	10
Naturalist	12		36	5		51							100
Poison													
Quininup	0		21	19		284							320
Readia													
Red Gully	1		36										40
Rosa													
Rushy	11		81			190							280
Scott	126	5345							535				6010
St John	30		409										440
Tanjannerup	1												0
Turner SW	19		229			8							260
Turnwood	3												0
Vasse Diversion	141	3343	20	148		99		513	57			567	4890
West Bay	11		17			121						268	420
Wilyabrup	45		43	21		1228							1340
Wonnerup	169	1892	75			133			471			172	2910
Total agricultural demand (kL)	1499	15666	13369	1152	60	8475	231	1369	5728	140	58	1880	49607

2.3 Discussion

The Whicher area's agricultural water demand is characterised by relatively high volumes of water used by a relatively small number of crops, which are concentrated within a small number of subareas. Irrigated pasture and crops, perennial horticulture and tree fruits, grapes and vegetables use more than 85 per cent of the Whicher area's agricultural water demand, but occupy only five per cent of the region's total agricultural land area. In contrast, grazing land makes up 94 per cent of the agricultural land in the Whicher area, but is responsible for only three per cent of the water used in agriculture.

Irrigated pastures and crops are often associated with dairy cattle. Irrigation techniques for pasture tend to be inefficient, which probably explains the high proportion of water consumed by this land use. Of the 15.6 GL/year of water used for irrigating pastures and crops in the Whicher area, the Scott subarea uses 34 per cent and the Vasse Diversion 21 per cent.

Perennial horticulture and tree fruits are the next-highest users of irrigation water in the Whicher area. Capel River north subarea uses around one third of the 13 GL used annually to irrigate this land use within the Whicher area. Water used for grape production is highest in the Wilyabrup subarea (14 per cent of all water used for grapes in Whicher) and the Dunsborough coast subarea (11 per cent of all water used for grapes).

It must be noted that water used in agriculture is drawn from both surface and groundwater sources. Total agricultural demand estimates on their own do not distinguish between these sources. However, using information such as groundwater licences and expert knowledge the proportion of total agricultural demand sourced from surface water can be estimated for each subarea. When this demand is combined with information on licensed use by other industries and domestic supply, then total surface water use can be calculated. This is detailed in Section 4 of this report.

2.3.1 Evaluation of the total agricultural demand method

The methods described in this section were designed to give a consistent, replicable and relatively rapid means of estimating total agricultural demand for the Whicher area. The estimates of agricultural demand can be cross-referenced and combined with other sources of information such as licensed entitlements, dam storage, expert knowledge and water-use surveys to check for accuracy and estimate the proportion that was sourced from surface water. However, several important limitations of the methods should be taken into account. Total agricultural demand is an estimate based on land-use mapping from aerial photography. The accuracy of this exercise can vary according to the individuals undertaking the mapping because of different interpretations and knowledge of local land uses. It may be difficult to use visual interpretation of aerial photography to distinguish between vegetables and irrigated

crops, for example. Land-use mapping has not yet been ground-truthed to assess the accuracy of the mapping.

The coding system used (ALUM – version 6) does not always provide the detail required for estimating water use. For example, it does not distinguish between land used for grazing different stock types (sheep, dairy cattle, beef cattle, ostriches etc.), which vary in their drinking rates per hectare. For example, dairy cattle consume approximately 94.5 kL/ha annually while beef cattle use about 8.5 kL/ha annually. Drinking rates for beef cattle were used rather than dairy cattle due to an assumption that less than three per cent of cleared grazing land was occupied by dairy cattle (DoW 2006, unpublished). Other categories are also broad. For example, seasonal horticulture assumes the same irrigation rates for all vegetables, regardless of species or breed.

When interpreting the estimates of total agricultural demand it is important to remember that:

- Mapping of land use from aerial photos only represents land use at the time the photo was taken and therefore becomes dated as land uses change or new land is developed.
- The agricultural demand method does not represent total water use for the Whicher area because it does not include water used for domestic purposes (both self supply and scheme water supply), tourism (restaurants, accommodation), mining and industry, or dairy- and wine-processing factories. These uses are usually licensed, and their water demand can be found using the department's Water Resource Licensing database.
- While total agricultural demand has been estimated, the source of the water was not determined; that is, whether water for agriculture is taken from surface water, groundwater or scheme water.

Overall, the methods used in this report have proven very useful given constraints on resources and time. Estimates of total agricultural demand have been particularly useful as an indication of surface water use for agriculture in the following areas:

- where agricultural water comes from surface sources, and is not a combination of surface water and groundwater
- where there is significant direct take, the estimates are believed to be more accurate than dam storage figures.

As licensing and metering information becomes available in the future, the accuracy of this method will become apparent and the methods will be refined where necessary.

3 Storage in farm dams

Farm dams are a common way to capture and use surface water in the Whicher area. Determining the amount of water stored in farm dams is part of the process to estimate the overall level of demand in the region. This section of the report details the methods used to map the distribution and surface area of farm dams in the Whicher area, as well as those used to estimate the total volume of water stored in dams (i.e. total capacity).

Dam storages were first estimated in 2006 and recalculated again in 2008. Both estimates were used in the Whicher planning process and therefore a description of the methods used and results gained from each of them are included in this report.

In 2006, dams in 15 subareas were mapped and an algorithm determined to estimate storage volume based on dam surface area. These dam storage volumes were used to estimate water use when setting allocation limits in early 2008.

Later in 2008, after allocation limits were set, dam mapping was extended to include most of the Whicher subareas and the algorithm to estimate dam storage from dam surface area was updated using more relevant dam storage information. While this information was not available when setting allocation limits for the draft Whicher plan (DoW 2008), the information was used to licence existing dams and to update the amount of water available for new licences in the final Whicher plan (DoW 2009b).

As a result of this work, the Department of Water's planning staff are confident they have gained useful information on the number of farm dams, their location and the total volume of water stored in them. In combination with the land-use mapping and crop-demand estimates (described in Section 2.2), these data have proven invaluable in informing the decision-making process for allocation planning.

The methods (Section 3.1) and results (Section 3.2) of both the 2006 and 2008 estimates of dam storage have been detailed below.

3.1 Methods

3.1.1 Mapping farm dams

Farm-dam mapping in seven rivers of south west Western Australia was first carried out in 2006 (SKM 2006). Five of these rivers fell within the Whicher area: Capel River, Wilyabrup Brook, Cowaramup Brook, Margaret River and Chapman Brook. Altogether, the areas mapped in 2006 included 15 of the 52 Whicher subareas. The mapping identified the location and surface area of dams.

The methods used to capture the location and surface area of dams included:

- manual digitising from aerial photography
- remote sensing capture from Digital Globe satellite imagery.

The aerial photography was supplied by Landgate and had a ground resolution of 0.5 m. Photography dates ranged from 2000 to 2004. The extent of this photography

and the dates the images were taken are shown in Figure 5. All 15 subareas were mapped using aerial photography. One subarea was also mapped from satellite imagery using eCognition remote sensing software to define and map dams[1].

The dataset produced included dam location, shape, surface area and identification number (Figure 5).

[1] The department tested the use of remote sensing from Digital Globe satellite imagery (captured on 6 January 2006) to map dams in the Wilyabrup catchment and compared it with the results of the manual capture from aerial photography. The comparison showed that remote sensing using satellite imagery is cost effective and produced accurate-enough results compared with manual capture from aerial photography to be useful for routine surveys of dam size at the subarea scale (SKM 2006).

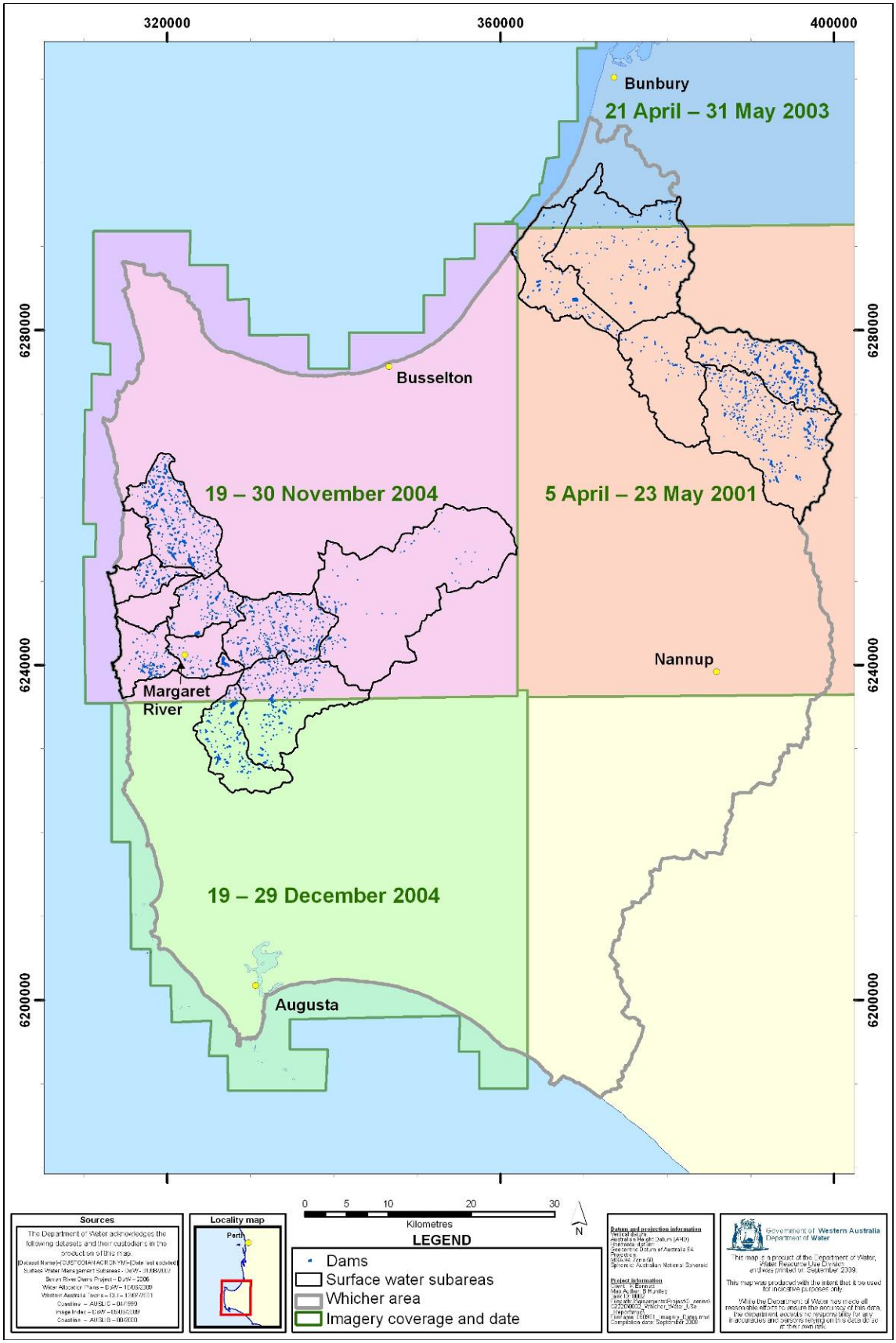

Figure 5 Dam mapping and aerial photo dates for the capture of farm dams in the 15 Whicher subareas

In 2008, farm-dam mapping was extended to include all proclaimed subareas and most unproclaimed subareas in the south west. This included most of the 52 Whicher subareas. Mapping was undertaken by SKM to produce a shape file of dam polygons. Aerial photography was used where available and dams were mapped manually. QuickBird satellite imagery was used in subareas for which no recent aerial photography was available (Figure 6) and dams were mapped using eCognition image analysis software. This dam mapping has not yet been post-processed to eliminate features that were not farm dams.

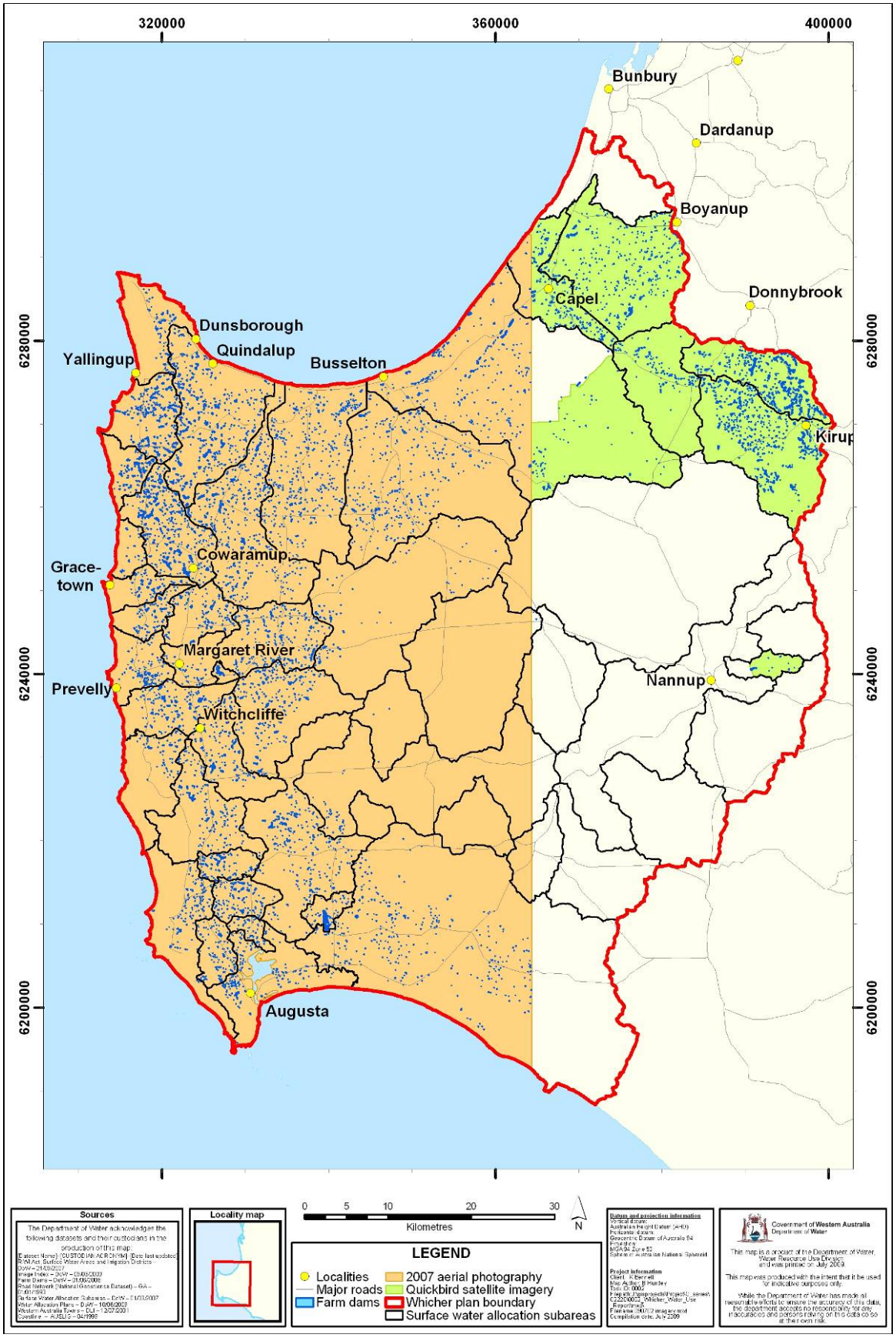

Figure 6 Mapped Whicher dams and area covered by 2007 aerial photography and 2006 and 2008 QuickBird satellite imagery

3.1.2 Estimating storage capacity of farm dams

The storage capacity of any dam depends on its shape, wall height and the site's slope. This information was not readily available for farms dams in the Whicher area. Instead, surface area was used to predict dam storage volumes. At the regional scale for relatively small dams, it has been shown that dam surface area is a useful predictor of regional total storage volumes (SKM 2004; DoW 2008, unpublished).

In 2006, a sample of 557 farm dams in south west Western Australia was used to develop an algorithm describing the surface-area-to-volume relationship for farm dams in the Whicher area (Boniecka 2006). Figure 7 shows the distribution of these dams in the south west. Figure 8 depicts a scatter plot of dam surface area and measured volume for the dams mapped and measured in this exercise.

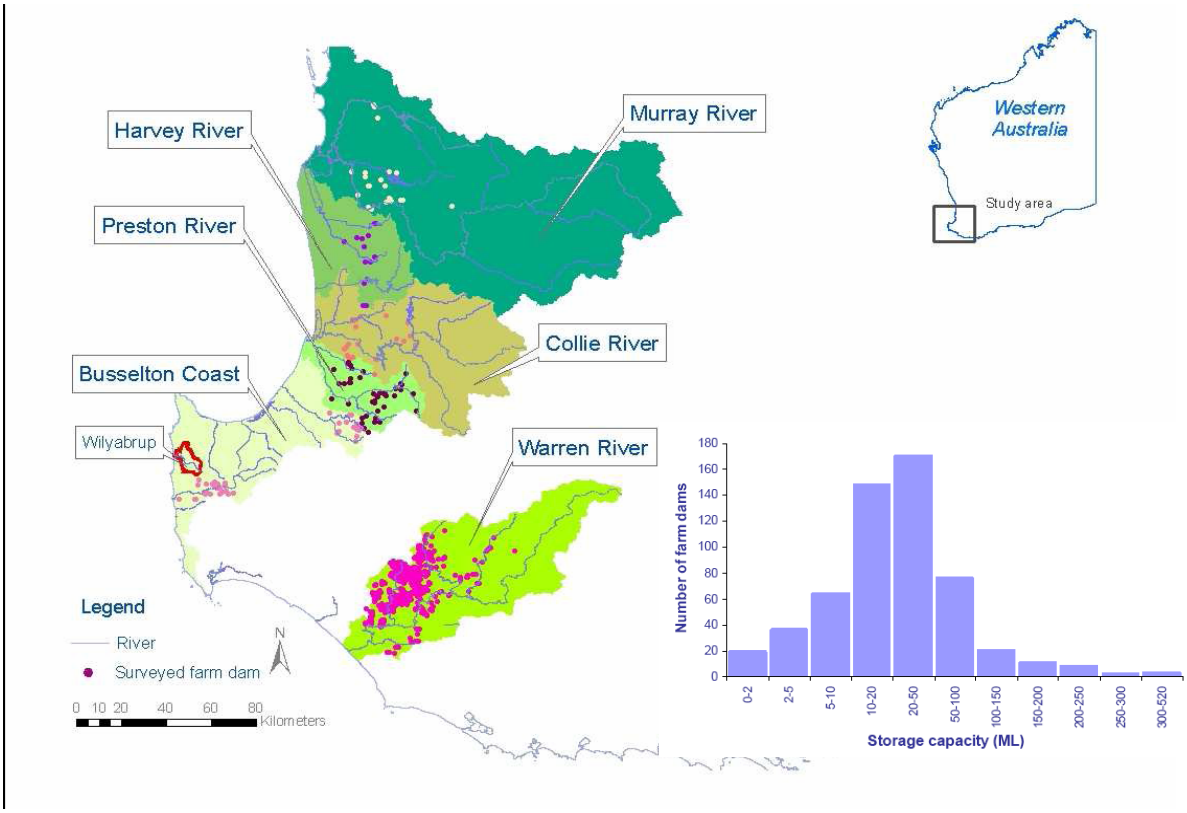

Figure 7 Location of dams used to develop a regional relationship between dam surface area and storage capacity (from Boniecka 2006). The histogram at the bottom right shows the range in dam size used to develop the relationship.

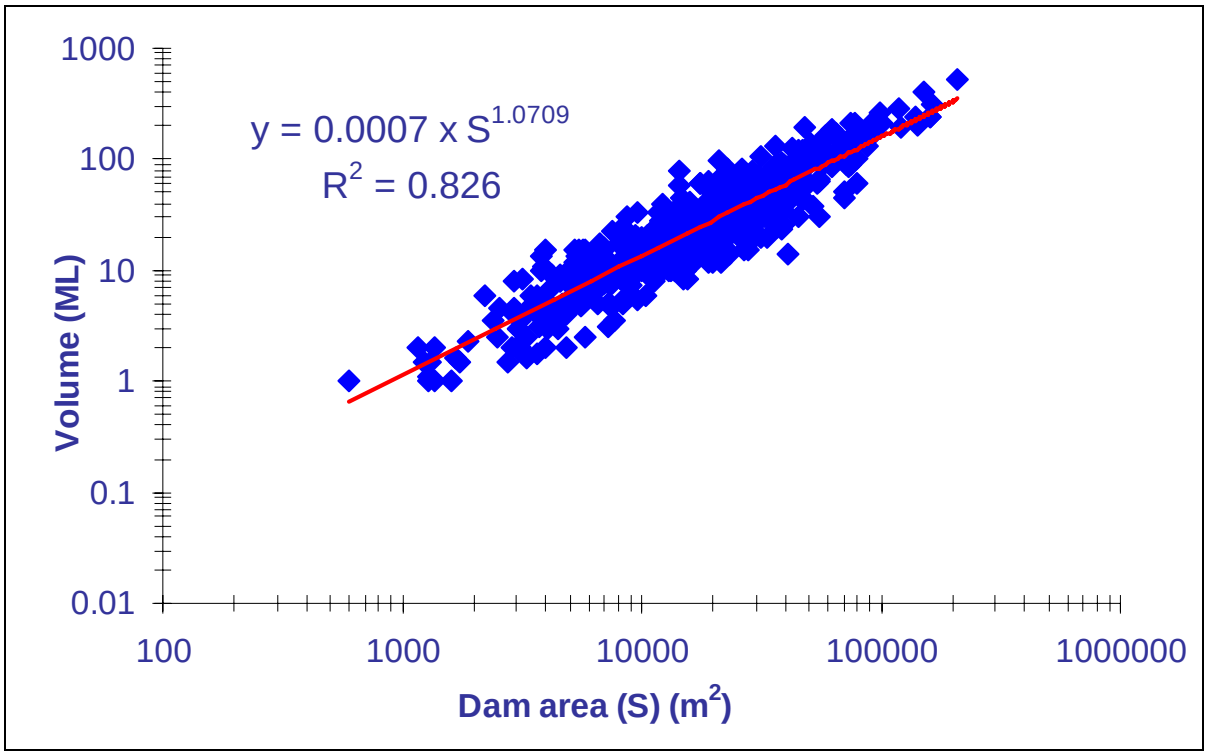

Figure 8 Scatter plot of the surface area and volume of licensed dams in the south west used to develop an algorithm to determine storage volumes of the surface area of dams mapped in 2006

$V = 0.0007 \times S^{1.0709}$

where:

V = storage capacity of a dam in ML

S = surface area of a dam in m^2

This algorithm was used to estimate total surface water use when setting allocation limits (Section 4.1.1 and Table 6).

Following licensing of the Wilyabrup subarea, which began early 2008, a second algorithm was developed. Site visits were undertaken for each licence application in the Wilyabrup subarea and more accurate dam volumes were calculated using parameters such as wall height, excavated material, gully shape, depth, width and length. These volumes were used to refine the relationship between surface area and storage capacity. Non-typical dams were excluded from the dataset, including spring dams, off-stream dams or those that were extensively excavated. Figure 9 illustrates the relationship between dam surface area and volume.

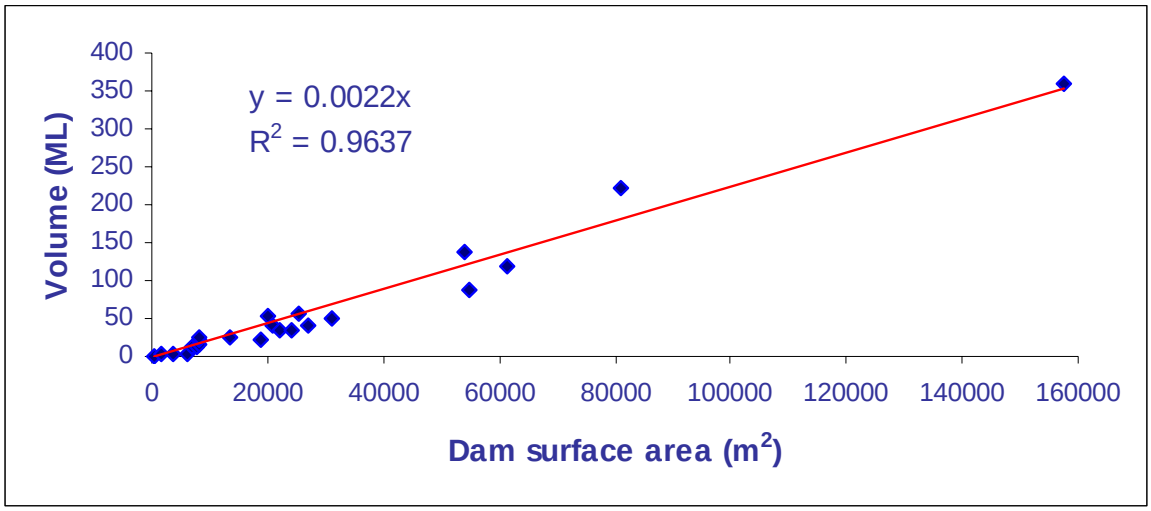

Figure 9 Scatter plot of the surface area and volume of Wilyabrup dams used to develop an algorithm to determine storage volumes of the surface area of dams mapped in 2008

Based on the data gathered in the Wilyabrup subarea, the refined algorithm used to estimate storage from the surface area of dams mapped in 43 Whicher subareas in 2008 was:

V = 0.0022 x S

where:

V = storage capacity of a dam in ML

S= surface area of a dam in m^2

This algorithm was used to estimate total surface water use when determining the additional water available for use in the allocation plan (Section 4.1.1 and Table 8).

3.2 Results

3.2.1 Dam storage

Table 5 indicates the total storage volume of dams in the Whicher subareas for which farm-dam mapping was undertaken. Subareas with no value for storage (–) in Table 5 were not mapped, whereas subareas with a zero for storage were mapped but had no dams over 8 ML in capacity.

Table 5 Total estimated dam storage in the Whicher subareas

Subarea name	Area of subarea (km^2)	Total storage (ML)		Storage density (ML/km^2)		Storage as % Whicher storage
		2006 estimate	2008 estimate	2006 estimate	2008 estimate	2008 estimate
10 Mile Brook**	5	490	630	101	130	3
Adelaide	64	-	0	-	0	0
Ballan	54	-	0	-	0	0
Beenup	17	-	0	-	0	0
Biljedup	21	-	30	-	1	0
Boodijidup	62	-	840	-	13	4
Bramley	47	580	770	12	16	3
Buayanyup	201	-	440	-	2	2
Calgardup	72	-	160	-	2	1
Capel River (central)	111	90	*100	1	1	0
Capel River (north)	88	1,800	*2440	21	28	11
Capel River (south) **	168	970	*1040	6	6	4
Capel River (west)	81	450	*390	6	5	2
Carbunup	165	-	1,270	-	8	5
Carlotta	160	-	-	-	-	-
Chapman	65	860	1,100	13	17	5
Chapman (upper)	118	960	1,110	8	9	5
Cowaramup	30	220	300	7	10	1
Dunsborough coast	158	-	2,140	-	14	9
Ellen	28	-	360	-	13	2
Ellis	44	-	-	-	-	-
Five Mile Brook	87	-	-	-	-	-
Glenarty	32	-	400	-	12	2
Gunyulgup	66	-	1,280	-	19	6
Gynudup Brook and Tren Creek	188	260	*260	1	1	1
Lwr Blackwd (estuarine)	184	-	420	-	2	2
Lwr Blackwd (Hardy)	100	-	200	-	2	1
Lwr Blackwd (Hut)	251	-	10	-	0	0
Lwr Blackwd (Nannup)	328	-	-	-	-	-
Margaret (lower)	45	220	220	5	5	1
Margaret (middle)	86	660	470	8	5	2
Margaret (upper)	273	170	190	1	1	1
Margaret town	32	60	60	2	2	0
McAtee	113	-	-	-	-	-
McLeod SW	95	-	420	-	4	2
Milyeannup	107	-	-	-	-	-

Subarea name	Area of subarea (km^2)	Total storage (ML)		Storage density (ML/km^2)		Storage as % Whicher storage
		2006 estimate	2008 estimate	2006 estimate	2008 estimate	2008 estimate
Naturalist	64	-	150	-	2	1
Poison	50	-	-	-	-	-
Quininup	30	-	560	-	18	2
Readia	20	-	0	-	0	0
Red Gully	133	-	-	-	-	-
Rosa	227	-	0	-	0	0
Rushy	23	-	270	-	12	1
Scott	702	-	290	-	0	1
St John	575	-	-	-	-	-
Tanjannerup**	21	-	100	-	5	0
Turner SW	96	-	190	-	2	1
Turnwood	12	-	20	-	2	0
Vasse Diversion	283	-	310	-	1	1
West Bay	31	-	240	-	8	1
Wilyabrup	89	2,190	3,070	25	34	13
Wonnerup	477	-	970	-	2	4

** Calculated using 2006 dam mapping with algorithm $V = 0.0007 \times S^{1.0709}$*

*** 10 Mile Brook, Capel River south and Tanjannerup subareas all have public water supply dams*

Excluding subareas with public water supply dams, the Capel River north and Wilyabrup subareas have the highest levels of dam storage (2440 and 3070 ML respectively). These subareas also have the highest volume of water stored per square kilometre, storing 28 and 34 ML/km^2 respectively (Table 5). Dunsborough coast has the third highest level of dam storage, with 2140 ML stored in dams.

3.3 Discussion

Dam mapping and storage calculations were used to estimate the level and intensity of surface water use in the Whicher subareas. Storage volumes for self-supply farm dams were assumed to represent surface water use for agriculture and some domestic use. There are also three public water supply dams in the Whicher area, including the 10 Mile Brook dam east of Margaret River, Kirup dam in the hills of the Capel River south subarea and Tanjannerup dam in the Tanjannerup subarea. Water from these dams also contributes to total surface water use.

Subareas with the highest storage density are 10 Mile Brook, Wilyabrup, Capel River north and Gunyulgup. These subareas store 130, 34, 28 and 19 ML/km^2 respectively. The 10 Mile Brook subarea contains a public water supply dam, whereas water storage in the other three catchments can be assumed to be mostly for agricultural use. As an initial indicator, the department would expect subareas with the highest

storage density to experience the greatest environmental impacts in relation to water storage. This will be further investigated in planning towards 2010.

It should be noted that a reasonable amount of direct pumping occurs in some areas of the Capel and Margaret rivers, highlighting the importance of local knowledge and expert opinion to interpret the results of dam storage and provide a realistic indication of surface water use. Section 4 provides detail on how total dam storage results were used in estimating total surface water use.

3.3.1 Evaluation of the farm-dam storage method

Dam storage figures were very useful in estimating surface water use in the Whicher area. While storage estimates are not always accurate for individual dams, they are accurate as an estimate of storage within a subarea. By comparing storage with agricultural demand, areas where estimates are significantly different are highlighted and further investigation can be undertaken to determine the reason for the difference – whether it be direct take, groundwater use or inaccuracies in either method. This is further discussed in Section 4.3.

Limitations of the dam mapping and storage calculation method include the following:

- the equation used to calculate dam storage generally underestimates the storage volume of large dams and overestimates the storage volume of small dams
- direct take from streams is not identified when using dam storage to indicate surface water use
- total dam storage volume overestimates water use if the entire volume of the dam is not used each year, and underestimates water use if dams fill more than once a year
- this method assumes water stored in dams is all surface water and does not include any groundwater capture
- dam mapping has not been extensively ground-truthed to verify mapping and exclude wetlands and other anomalies that appear to be dams on aerial photographs.

4 Total surface water use

This section outlines the methods used to estimate total surface water use in the Whicher area. It builds on the information presented in sections 2 and 3 on agricultural demand and dam storage. Licensed use in mining and industry and public water supply are also taken into account for calculating total surface water use. The results have been used to set allocation limits and to determine the availability of additional water for use.

4.1 Methods

4.1.1 Estimating total surface water use

The water-use information gathered by estimating agricultural demand (Section 2) and farm-dam storage (Section 3) was combined with other information to estimate total surface water use within the Whicher subareas. The decision-making process applied to estimating total surface water use was as follows:

1. Where complete surface water licensing existed in the subarea, the sum of the licensed entitlements was used to represent total surface water use.
2. If surface water licensing in a subarea was incomplete, the following methods were employed:
    - Where dam storage was greater than agricultural demand, dam storage volume was assumed to represent surface water use for agriculture. Any surface water entitlements or use figures for large industry and public water supply were added to surface water estimates for agriculture to represent total surface water use.
    - Where total agricultural demand was greater than dam storage, the following methods were employed to estimate surface water demand from total demand:
        - If complete groundwater licensing existed in the subarea, surface water demand was estimated by removing groundwater entitlements for agriculture from total agricultural demand estimates. Any surface water entitlements or use figures for large industry and public water supply were added to this to represent total surface water use.
        - If groundwater licensing was incomplete, regional knowledge of use practices within the subarea was applied to total agricultural demand estimates to find the percentage of total agricultural demand that was sourced from surface water. Any surface water entitlements or use figures for large industry and public water supply were added to this to represent total surface water use.

When dam mapping was extended and water-use estimates were updated, the initial total water-use estimates were compared with dam storage estimates and expert opinion was used to decide which estimate was most accurate. In most cases dam storage estimates were used to represent surface water use for agriculture. Any

surface water entitlements or use figures for large industry and public water supply were added to this to represent total surface water use.

4.2 Results

4.2.1 Total surface water use – initial estimate

The initial estimates of total surface water use were used at the time allocation limits were set, as outlined in the draft Whicher allocation plan (DoW 2008). For those subareas where the allocation limit was set at current use, the figures used were drawn from Table 6.

Subareas with the highest annual surface water use were Scott (6010 ML), Capel River north (4700 ML) and Wilyabrup (2190 ML). Table 6 also displays the method of surface water estimation.

Table 6 Initial surface-water-use estimates as at the release of the draft allocation plan (DoW 2008), using total agricultural demand, farm-dam mapping of 15 subareas and other sources of information

Subarea name	Total agricultural demand (ML)	Dam storage (ML)	Public water supply (ML)	Initial use estimate (ML)	Use estimate method
10 Mile Brook	0	490	1,000	1000	Lic. PWS
Adelaide	0			0	Total agricultural demand
Ballan	0			0	Total agricultural demand
Beenup	950			0	No surface water use (expert opinion)
Biljedup	40			38	Total agricultural demand
Boodijidup	700			700	Total agricultural demand
Bramley	290	580		290	Total agricultural demand
Buayanyup	6120			0	No surface water use (expert opinion)
Calgardup	80			84	Total agricultural demand
Capel River (central)	1510	90		980	Total agricultural demand – licensed GW
Capel River (north)	4700	1800		4700	Total agricultural demand
Capel River (south)	2580	970	40	2540	Total agricultural demand – licensed GW
Capel River (west)	1890	450		490	Total agricultural demand – licensed GW
Carbunup	1430			1430	Total agricultural demand
Carlotta	510			510	Total agricultural demand
Chapman	500	860		860	Dam storage (> total agricultural demand)
Chapman (upper)	830	960		960	Dam storage (> total agricultural demand)
Cowaramup	230	220		230	Total agricultural demand
Dunsborough coast	2320			930	% total agricultural demand (expert opinion)
Ellen	200			200	Total agricultural demand
Ellis	0			0	Total agricultural demand
Five Mile Brook	1250			0	% total agricultural demand (expert opinion)
Glenarty	280			280	Total agricultural demand

Subarea name	Total agricultural demand (ML)	Dam storage (ML)	Public water supply (ML)	Initial use estimate (ML)	Use estimate method
Gunyulgup	660			660	Total agricultural demand
Gynudup Brook and Tren Creek	2010	260		100	% total agricultural demand (expert opinion)
Lwr Blackwd (estuarine)	450			450	Total agricultural demand
Lwr Blackwd (Hardy)	40			37	Total agricultural demand
Lwr Blackwd (Hut)	40			40	Total agricultural demand
Lwr Blackwd (Nannup)	880			880	Total agricultural demand
Margaret (lower)	530	220		530	Total agricultural demand
Margaret (middle)	1110	660	770	1880	Total agricultural demand + PWS use (> lic. SW or dam storage)
Margaret (upper)	70	170		170	Dam storage (> total agricultural demand or lic. SW)
Margaret town	30	60		64	Dam storage (> total agricultural demand)
McAtee	0			0	State forest – assume no use
McLeod SW	380			380	Total agricultural demand
Milyeannup	10			5	Total agricultural demand
Naturalist	100			100	Total agricultural demand
Poison	0			0	State forest – assume no use
Quininup	320			320	Total agricultural demand
Readia	0			0	State forest – assume no use
Red Gully	40			40	Total agricultural demand
Rosa	0			0	State forest – assume no use
Rushy	280			260	Total agricultural demand – licensed GW
Scott	6010			6010	Total agricultural demand
St John	440			440	Total agricultural demand
Tanjannerup	0		140	140	Lic. PWS
Turner SW	260			260	Total agricultural demand
Turnwood	0			3	Total agricultural demand
Vasse Diversion	4890			240	% total agricultural demand (expert opinion)
West Bay	420			420	Total agricultural demand
Wilyabrup	1340	2190		2190	Dam storage (> total agricultural demand)
Wonnerup	2910			150	% total agricultural demand (expert opinion)

4.2.2 Total surface water use – final estimate

The surface water estimates shown in Table 8 were used to determine the level of water availability in the final Whicher allocation plan (DoW 2009b). Table 8 also displays the method of surface water estimation. Water-use figures were updated using new dam storage figures and licensing information for Capel River west.

Using the updated estimates of surface water use, the highest use areas were Capel River north (4700 ML), Wilyabrup (3070 ML) and Capel River south (2540 ML).

Table 7 Final total surface-water-use estimates using total agricultural demand, farm-dam mapping of 43 Whicher subareas and other sources of information. Used to estimate available water in the final allocation plan (DoW 2009b).

Subarea name	Total agricultural demand (ML)	Dam Storage (ML)	Public water supply (ML)	Updated use estimate (ML)	Use estimate method
10 Mile Brook	0	630	1000	1000	Lic. PWS
Adelaide	0	0		0	State forest – assume no use
Ballan	0	0		0	State forest – assume no use
Beenup	950	0		0	No surface water use (expert opinion)
Biljedup	40	30		38	Total agricultural demand
Boodijidup	700	840		840	Dam storage (> total agricultural demand)
Bramley	290	770		770	Dam storage (> total agricultural demand)
Buayanyup	6120	440		440	Dam storage (< total agricultural demand) (expert advice)
Calgardup	80	160		150	Dam storage (> total agricultural demand)
Capel River (central)	1510	100		980	Total agricultural demand – licensed GW
Capel River (north)	4700	2440		4700	Total agricultural demand
Capel River (south)	2580	1040	40	2540	Total agricultural demand – licensed GW
Capel River (west)	1890	390		1184	Licensed
Carbunup	1430	1270		1430	Total agricultural demand
Carlotta	510	–		510	Total agricultural demand
Chapman	500	1100		1100	Dam storage (> total agricultural demand)
Chapman (upper)	830	1110		1110	Dam storage (> total agricultural demand)
Cowaramup	230	300		300	Dam storage (> total agricultural demand)
Dunsborough coast	2320	2140		2140	Dam storage (< total agricultural demand) (expert advice)
Ellen	200	360		360	Dam storage (> total agricultural demand)
Ellis	0	–		0	State forest – assume no use
Five Mile Brook	1250	–		0	No surface water use
Glenarty	280	400		400	Dam storage (> total agricultural demand)
Gunyulgup	660	1280		1280	Dam storage (> total agricultural demand)
Gynudup Brook and Tren Creek	2010	260		260	Dam storage (< total agricultural demand) (expert advice)
Lwr Blackwd (estuarine)	450	420		450	Total agricultural demand
Lwr Blackwd (Hardy)	40	200		200	Dam storage (> total agricultural demand)
Lwr Blackwd (Hut)	40	10		40	Total agricultural demand
Lwr Blackwd (Nannup)	880	–		880	Total agricultural demand
Margaret (lower)	530	219		530	Total agricultural demand
Margaret (middle)	1110	470	770	1880	Total agricultural demand + PWS use (> lic. SW or dam storage)

Subarea name	Total agricultural demand (ML)	Dam Storage (ML)	Public water supply (ML)	Updated use estimate (ML)	Use estimate method
Margaret (upper)	70	190		190	Dam storage (> total agricultural demand or lic. SW)
Margaret town	30	60		126	Dam storage (> total agricultural demand)
McAtee	0	–		0	State forest – assume no use
McLeod SW	380	420		420	Dam storage (> total agricultural demand)
Milyeannup	10	–		5	Total agricultural demand
Naturalist	100	150		150	Dam storage (> total agricultural demand)
Poison	0	–		0	State forest – assume no use
Quininup	320	560		560	Dam storage (> total agricultural demand)
Readia	0	0		0	State forest – assume no use
Red Gully	40	–		40	Total agricultural demand
Rosa	0	0		0	State forest – assume no use
Rushy	280	270		590	Dam storage + new license (> total agricultural demand)
Scott	6010	290		290	Dam storage (< total agricultural demand) (expert advice)
St John	440	–		440	Total agricultural demand
Tanjannerup	0	100	140	140	Lic. PWS
Turner SW	260	190		260	Total agricultural demand
Turnwood	0	20		20	Dam storage (> total agricultural demand)
Vasse Diversion	4890	310		310	Dam storage (< total agricultural demand) (expert advice)
West Bay	420	240		420	Total agricultural demand
Wilyabrup	1340	3070		3070	Dam storage (> total agricultural demand)
Wonnerup	2910	970		970	Dam storage (< total agricultural demand) (expert advice)

PWS = public water supply, GW = groundwater, SW = surface water

4.3 Discussion

This report has described the methods used to estimate total surface water use in the Whicher area. Water use was estimated in two phases: once in the lead up to the release of the draft Whicher allocation plan (DoW 2008), and again as part of the preparation of the final allocation plan (DoW 2009b).

The initial estimates discussed in Section 4.2.1 were used in setting allocation limits in the draft Whicher allocation plan. At this time, information on farm-dam storage was only available for 15 subareas. Between the time the draft plan was released and the final allocation plan was published, more dam mapping became available and the equation to calculate storage from surface area was refined.

Although use estimates were updated in the final allocation plan, the department decided not to change the allocation limits set out in the draft plan, however the updated use estimates were used to recalculate available water (see DoW 2009a) for the final plan (DoW 2009b). Available water was calculated by subtracting the total

estimated surface water use from the allocation limit. This information is critical for assessing licence applications for new use.

The updated use estimates will help the department review the Whicher allocation limits – a commitment we made in the allocation plan (DoW 2009a).

4.3.1 Interpretation and limitations of total surface water estimates

Comparison of total agricultural demand and dam storage shows these estimation methods often produce different results (Table 8), but they can also give some insight into what is occurring in a subarea. For example, areas where total agricultural demand is greater than dam storage may indicate significant groundwater use (Buayanyup) or possible direct take (Capel River north). Areas where dam storage is higher than total agricultural demand may indicate dams are not being fully utilised (Wilyabrup). These differences serve to highlight the importance of sourcing knowledge of use practices in the subarea so the department can interpret the information correctly.

Inaccuracies in estimates of surface water use are largely based on the limitations of estimating total agricultural demand and dam storage, as discussed in sections 2.3.1 and 3.3.1. A limitation in the method for estimating total surface water use was that in some subareas the agricultural demand, dam storage and licensing information did not accurately reflect the subarea's water-use practices. For these subareas the department relied on people with local knowledge about the level of groundwater use and direct pumping, for example, in combination with other sources of information.

Following licensing, which is currently underway in newly proclaimed areas, the department will update these estimates where needed.

5 Recommendations

As discussed previously, there are limitations to the methods used to estimate total surface water use in this report. These include suitability of the current algorithm to estimate dam storage from the dam surface area, inaccuracies in land-use mapping using aerial photography, and trying to decipher how much of the total agricultural demand is sourced from surface water and how much is from groundwater. These limitations will be solved through licensing. Therefore it is recommended that:

- all proclaimed areas are licensed to help manage the resource and provide accurate water-use figures.

In the event that the methods in this report are applied to other areas, or the unproclaimed Whicher areas continue to rely on these methods, it is recommended that:

- ground-truthing for land-use mapping and dam mapping takes place
- water-use estimates are updated as more accurate crop-demand and land-use mapping becomes available
- the equation used to calculate storage is updated to suit different regions as better information becomes available.

Land uses change over time as a result of economic drivers and climatic influences. Where land-use mapping continues to be used for estimating water use it is recommended that:

- mapping is updated periodically to reflect changes in land use (in areas not subject to rapid change, every five years should be enough; in areas that are rapidly changing and not licensed, more regular mapping may be required).

Appendices

Appendix A Australian land use and management classifications

1 Conservation and natural environments

1.1.0 Nature conservation
1.1.1 Strict native reserves
1.1 2 Wilderness areas
1.1.3 National park
1.1.4 Natural feature protection
1.1.5 Habitat/species management area
1.1.6 Protected landscape

1.1.7 Other conserved area

1.2.0 Managed resource protection
1.2.1 Biodiversity
1.2.2 Surface water supply
1.2.3 Groundwater
1.2.4 Landscape
1.2.5 Traditional indigenous uses

1.3.0 Other minimal use
1.3.1 Defence
1.3.2 Stock route
1.3.3 Residual native cover
1.3.4 Rehabilitation

2 Production from relatively natural environments

2.1.0 Grazing natural vegetation

2.2.0 Production forestry
2.2.1 Wood production
2.2.2 Other forest production

3 Production from dryland agricultural and Plantations

3.1.0 Plantation forestry
3.1.1 Hardwood production
3.1.2 Softwood production
3.1.3 Other forest production
3.1.4 Environmental

3.2.0 Grazing modified pastures

3.2.1 Native/exotic pasture mosaic
3.2.2 Woody fodder plants
3.2.3 Pasture legumes
3.2.4 Pasture legume/grass mixtures
3.2.5 Sown grasses

3.3.0 Cropping
3.3.1 Cereals
3.3.2 Beverage & spice crops
3.3.3 Hay & silage
3.3.4 Oil seeds
3.3.5 Sugar
3.3.6 Cotton
3.3.7 Tobacco

3.3.8 Legumes

3.4.0 Perennial horticulture
3.4.1 Tree fruits
3.4.2 Oleaginous fruits

3.4.3 Tree nut

3.4.4 Vine fruits

3.4.5 Shrub nuts fruits & berries

3.4.6 Flowers & bulbs
3.4.7 Vegetables & herbs

3.5.0 Seasonal horticulture
3.5.1 Fruits
3.5.2 Nuts
3.5.3 Flowers & bulbs
3.5.4 Vegetables & herbs

3.6.0 Land in transition
3.6.1 Degraded land
3.6.2 Abandoned land
3.6.3 Land under rehabilitation
3.6.4 No defined use

4 Production from irrigated agriculture and plantations

4.1.0 Irrigated plantation forestry
4.1.1 Irrigated hardwood production
4.1.2 Irrigated softwood production
4.1.3 Irrigated other forest production
4.1.4 Irrigated environmental

4.2.0 Irrigated modified pastures

4.2.1 Irrigated woody fodder plants
4.2.2 Irrigated pasture legumes
4.2.3 Irrigated legume/grass mixtures
4.2.4 Irrigated sown grasses

4.3.0 Irrigated cropping
4.3.1 Irrigated cereals
4.3.2 Irrigated beverage & spice crops
4.3.3 Irrigated hay & silage
4.3.4 Irrigated oil seeds
4.3.5 Irrigated sugar
4.3.6 Irrigated cotton
4.3.7 Irrigated tobacco
4.3.8 Irrigated legumes

4.4.0 Irrigated perennial horticulture

4.4.1 Irrigated tree fruits
4.4.2 Irrigated oleaginous fruits
4.4.3 Irrigated tree nut

4.4.4 Irrigated vine fruits

4.4.5 Irrigated shrub nuts fruits & berries

4.4.6 Irrigated flowers & bulbs

4.4.7 Irrigated vegetables & herbs

4.5.0 Irrigated seasonal horticulture
4.5.1 Irrigated fruits
4.5.2 Irrigated nuts
4.5.3 Irrigated flowers and bulbs
4.5.4 Irrigated vegetables & herbs

4.6.0 Irrigated land in transition
4.6.1 Degraded irrigated land
4.6.2 Abandoned irrigated land
4.6.3 Irrigated land under rehabilitation
4.6.4 No defined use (irrigation)

5 Intensive uses

5.1.0 Intensive horticulture
5.1.1 Shade houses
5.1.2 Glasshouses
5.1.3 Glasshouses (hydroponics)

5.2.0 Intensive animal production
5.2.1 Dairy

5.2.2 Cattle
5.2.3 Sheep
5.2.4 Poultry
5.2.5 Pigs
5.2.6 Aquaculture

5.3.0 Manufacturing and industrial

5.4.0 Residential
5.4.1 Urban residential
5.4.2 Rural residential
5.4.3 Rural living

5.5.0 Services

5.5.1 Commercial services
5.5.2 Public services

5.5.3 Recreation and culture
5.5.4 Defence facilities
5.5.5 Research facilities

5.6.0 Utilities

5.6.1 Electricity generation/ transmission
5.6.2 Gas treatment, storage and transmission

5.7.0 Transport and communication
5.7.1 Airports/aerodromes
5.7.2 Roads
5.7.3 Railways
5.7.4 Ports and water transport
5.7.5 Navigation and communication

5.8.0 Mining
5.8.1 Mines
5.8.2 Quarries
5.8.3 Tailings

5.9.0 Waste treatment and disposal
5.9.1 Stormwater
5.9.2 Landfill
5.9.3 Solid garbage
5.9.4 Incinerators
5.9.5 Sewage

6 Water

6.1.0 Lake
6.1.1 Lake – conservation
6.1.2 Lake – production
6.1.3 Lake – intensive use

6.2.0 Reservoir/dam
6.2.1 Reservoir
6.2.2 Water storage – intensive use/farm dams
6.2.3 Evaporation basin
6.2.4 Effluent pond

6.3.0 River
6.3.1 River – conservation
6.3.2 River – production
6.3.3 River – intensive use

6.4.0 Channel/aqueduct
6.4.1 Supply channel/aqueduct
6.4.2 Drainage channel/aqueduct

6.5.0 Marsh/wetland
6.5.1 Marsh/wetland – conservation
6.5.2 Marsh/wetland – production
6.5.1 Marsh/wetland – intensive use

6.6.0 Estuary/coastal waters
6.6.1 Estuary/coastal waters – conservation
6.6.2 Estuary/coastal waters – production
6.6.3 Estuary/coastal waters – intensive use

Appendix B Sources and options used to determine demand factors

		Irrigation calculator options					
Description	**ALUM code**	**Zone**	**Soil**	**Perennial or annual**	**Crop**	**Irrigation efficiency**	**Planting season**
Irrigated modified pastures	4.2.0	Manjimup, Margaret River	Sand, clay	perennial	lucerne	1.2	automatic
Irrigated legume/grass mixtures	4.2.3	Manjimup, Margaret River	Sand, clay	perennial	lucerne	1.2	automatic
Irrigated cropping	4.3.0	Manjimup, Margaret River	Sand, clay	perennial	lucerne	1.2	automatic
Irrigated perennial horticulture	4.4.0	Manjimup, Margaret River	Sand, clay	perennial	avocado	1.2	automatic
Irrigated tree fruits	4.4.1	Manjimup, Margaret River	Sand, clay	perennial	avocado	1.2	automatic
Irrigated oleaginous fruits	4.4.2	Manjimup, Margaret River	Sand, clay	perennial	olives	1.2	automatic
Irrigated tree nuts	4.4.3	Manjimup, Margaret River	Sand, clay	perennial	almonds	1.2	automatic
Irrigated vine fruits	4.4.4	Manjimup, Margaret River	Sand, clay	perennial	grapes	1.2	automatic
Irrigated shrub nuts fruits & berries	4.4.5	Manjimup, Margaret River	Sand, clay	perennial	berries	1.2	automatic
Irrigated flowers & bulbs	4.4.6	Manjimup, Margaret River	Sand, clay	perennial	native flowers	1.2	automatic
Irrigated seasonal horticulture	4.5.0	Manjimup, Margaret River	Sand, clay	perennial	onions	1.2	Nov plant date
Irrigated fruits	4.5.1	Manjimup, Margaret River	Sand, clay	perennial	strawberries	1.2	automatic
Irrigated vegetables & herbs	4.5.4	Manjimup, Margaret River	Sand, clay	perennial	onions	1.2	Nov plant date
Intensive horticulture	5.1.0	Manjimup, Margaret River	Clay always	annual	tomatoes	1.2	Ave of plant dates
		Other source					
Recreation and culture	5.5.3	DoW *General water application rates* (2006)					
Grazing natural vegetation	2.1.0	Water-use survey for Wilyabrup 2006 and DoW *General water application rates* as at 2006					
Grazing modified pastures	3.2.0	Water-use survey for Wilyabrup 2006 and DoW *General water application rates* as at 2006					

Glossary

Allocation limit Annual volume of water set aside for use from a water resource.

Catchment Area of land from which rainfall runoff contributes to a single watercourse, wetland or aquifer.

Commercial use Water taken from a resource that is directly or indirectly used for commercial purposes. This includes water taken for public and private purposes and water stored in a dam.

Current water use Total amount of water that is taken from surface water resources including licensed and unlicensed use.

Dam An embankment constructed to store or regulate surface water flow. A dam can be constructed in or outside a watercourse.

Environment Living things, their physical, biological and social surroundings, and the interactions between them.

Evaporation Loss of water from the water surface or from the soil surface by vaporisation due to solar radiation.

Flow Streamflow in terms of m^3/yr, m^3/d or ML/yr. May also be referred to as discharge.

Groundwater Water that occupies the pores and crevices of rock or soil beneath the land surface.

Hectare A surface measure of area equal to 10 000 square metres or approximately 2.47 acres.

Licence A formal permit that entitles the licence holder to ‘take’ water from a watercourse, wetland or underground source.

Licensed use Total (annual) volume of surface water that has been allocated to licensees as entitlements. This may include what is taken for public and private purposes and what can be taken to be stored in a dam.

On-stream storage Storages (such as farm dams) that are built on or within a defined waterway or watercourse.

Proclaimed resource

An area proclaimed under the *Rights in Water and Irrigation Act 1914* to enable water licensing, that is used for water allocation planning and management.

Surface water is proclaimed as a surface water area, irrigation district or proclaimed river under Part III Division 1B s.6 of the Act.

Self-supply

Water diverted from a source by a individual, company or public body for their own private use.

Spring

A spring is where water naturally rises to and flows over the surface of land.

Stock and domestic water use

Water that is used for ordinary domestic purposes associated with a dwelling, such as: water for cattle or stock other than those being raised under intensive conditions; water for up to 0.2 hectares (if groundwater) or 2 hectares (if surface water) of garden from which no produce is sold. This take is generally considered a basic right.

Subarea

A sub-division within a Surface or Groundwater Area, defined for the purpose of managing the allocation of groundwater resources. Sub-areas are not proclaimed and can therefore be changed internally without being gazetted.

Surface water

Water flowing or held in streams, rivers and other wetlands on the surface of the landscape.

Surface water management area

An area defined by the Department of Water, used for water allocation planning and management, which is generally a hydrologic basin or part of a basin.

Use

Water taken for private-benefit consumptive purposes including irrigation, industry, urban, stock and domestic, aesthetics, lifestyle and storage.

Watercourse

a Any river, creek, stream or brook in which water flows.

b Any collection of water (including a reservoir) into, through or out of which any thing coming within paragraph (a) flows.

c Any place where water flows that is prescribed by local by-laws to be a watercourse.

A watercourse includes the bed and banks of anything referred to in paragraphs a), b) or c).

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